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On the role of the mora in phonological analysis

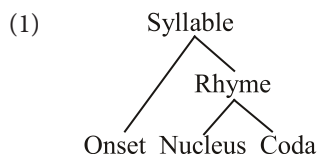
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Introduction

Linguistic phenomena often exhibit asymmetric behavior. Consider, for instance, a word of the type CCVCC, composed of a single vowel preceded and followed by two consonants. With respect to a number of phenomena, the prevocalic consonants behave differently from the postvocalic ones. One example of this asymmetry is the distribution of sonority. In almost all languages sonority rises in the prevocalic sequence, but falls in the postvocalic sequence (SIEVERS, 1881). In a language like Dutch, for instance, words like *krot* ‘hovel’ and *kort* ‘short’ obey this generalization and are therefore possible Dutch words. On the other hand, words like *rkot* and *kotr*, which violate it, are impossible.

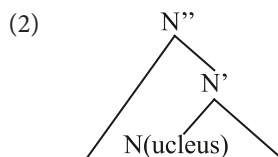
As it turns out, the rising-falling sonority profile found in Dutch words with a single vowel is not typical for words of this type, but of words in general, on the assumption that words consist of a sequence of syllables. As a matter of fact, the number of syllables that a word comprises can be derived from the number of sonority peaks that it contains. Similarly, syllable boundaries can be allocated with reference to the sonority troughs (cf. MILLIKEN, 1988, WETZELS, 1989). In line with Pike & Pike (1947), Kuryłowicz (1948), Fudge (1969), Selkirk (1982), and others, we represent the structure of the syllable as in (1).



This specific representation of the syllable captures the fact that prevocalic consonants can behave differently from the postvocalic ones because they are located in different constituents: one may say that in the domain of the onset sonority must rise, whereas it must fall in the domain of the coda. Also, many languages show a difference in the number of consonants allowed in the syllable onset and coda. In this case, the number of coda consonants is a subset of the number of consonants that are possible in the onset, as in Brazilian Portuguese. In this language the whole set of consonants and glides are possible onsets, but only sonorant consonants, glides and the fricative /s/ are allowed in the coda.

The representation in (1) has another advantage. Although the onset and the coda are both string adjacent to the vowel, they are not equidistant to the vowel from a hierarchical perspective. From a structural point of view, the coda is closer to the nucleus than the onset, because the former constituents are dominated by the rhyme node, which does not also dominate the onset. Given this structure, the syllable representation in (1) can account for the fact that in many languages the number of consonants in the coda interacts with the length of the vowel, while the number of consonants in the onset does not show such interaction. We again take Dutch as an example. In this language, the number of consonants that may appear in the onset is independent of the length of the nucleus. We thus find words like *kaas* ‘cheese’ and *Klaas* (proper name), both with a long vowel, next to *kas* ‘greenhouse’ and *klas* ‘class’, with a short vowel. The same freedom in combining the vowel with consonants does not exist inside the rhyme. Whereas Dutch has words like *kaak* ‘jaw’ and *kaal* ‘bald’, a word like *kaalk* (with a long vowel followed by two consonants) is ungrammatical, only a short vowel is possible before the sequence *lk*, as in *kalk* ‘chalk’.

The representation in (1) is replaced by a more economic one by Levin (1985), who proposes a syllable representation quite similar to syntactic phrase structure. The rhyme and the syllable node have the status of projections of the nucleus, in much the same way as higher level syntactic phrases are projections of a major lexical category.



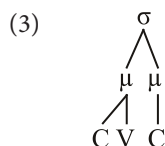
In the same year in which Blevins proposed her model of the syllable, Hyman (1985) proposed a formal equivalent of the classical concept of the “mora”. In the classical languages, poetic meter was based on the “measure” or “foot”, which consisted of a limited number of syllables. The number of syllables allowed in a

foot was dependent on the “length” of the syllables as well as on the chosen foot type. In the Latin verse a syllable is considered “long”, when it contains either a long vowel, a diphthong, or a short vowel followed by at least one consonant (including the first part of a geminate consonant). A “short” syllable contains a rhyme that consists of a single short vowel. With regard to the construction of the meter, a long syllable, which has two “times” or moras, is equivalent to two short syllables, which have one mora each. The following verse from Ovid is built according to the dactylic hexameter, the most popular of classical meters:

(quám.vis)(sínc su.b a)(quá, su.b a)(quá. ma.le)(dí.ce.re)(témp.tant)
Even though they are under water, under water they attempt to curse

The dactylic hexameter uses verses of six feet. In the example given, the first and last foot are spondees, each consisting of two long (bimoraic) syllables, whereas the other feet are dactyls, which consist of one long syllable followed by two short (monomoraic) syllables. The initial syllable of either foot is called the “ictus”, the basic beat of the verse, indicated with an accent in the example above. Observe that the notion of mora in classical meter exclusively refers to the segment structure of the syllable rhyme.

The recognition of the mora as a prosodic category of phonological theory is commonly traced back to Trubetzkoy (1939), although his view of the mora was essentially different from the one formalized, for example, by Hyman (1985), whose mora concept is almost identical to the one used in classical versification (cf. WETZELS (2002) for extensive discussion). Hyman expresses the fact that onset and coda consonants exhibit asymmetric behavior by assigning them a different moraic structure. In Hyman’s proposal, vowels are always moraic. On the other hand, while a postvocalic consonant can carry its own mora, the prevocalic consonant always integrates the mora of the following vowel, as is shown in (3).



In languages where the postvocalic consonant carries its own mora, the syllable counts as heavy. In languages where the coda consonant does not carry its own mora, it does not add weight to the syllable, and therefore counts as light. Over the years, moraic theory has become dominant in phonological theory, to the extent that now it has eliminated almost completely its alternatives in (1) and (2). In this article we give an overview of the most important phenomena that are analyzed in terms of moras. We will focus on those phenomena that allow us

to compare moraic theory and other theories of the syllable. These phenomena are syllable weight (section 2), compensatory lengthening (section 3), and the representation of geminate consonants (section 4).

1. Heavy and light syllables

Many languages make a distinction between heavy and light syllables for the sake of main stress allocation. In these languages heavy syllables attract stress, whereas light syllables do not. Latin is a well-known example (HAYES, 1995). In this language, the antepenultimate syllable receives the main stress, but only if the penult syllable is light. If the penultimate syllable is heavy, then it attracts itself the stress. Stress is never on a word-final syllable in Latin. This syllable does not count for the sake of stress assignment and is called “extrametrical”.

To fully understand the stress rule of Latin, it is important to know that in this language short vowels contrast with long ones. The minimal pairs in (4), which show the length contrast for all the vowels of the Latin vowel system, are taken from Gussenhoven & Jacobs (1998, p. 209). In the examples, the diacritic \sim marks the short vowels, while the diacritic \bar marks the long vowels.

(4)	p \ddot{o} pulus	people	p \bar{o} pulus	poplar tree
	m \ddot{a} lum	misfortune	m \bar{a} lum	apple
	l \ddot{i} ber	book	l \bar{i} ber	free
	l \ddot{e} go	I read	l \bar{e} go	I appoint as delegate
	f \ddot{u} ror	fury	f \bar{u} ror	I steal

For the proper functioning of the stress rule, the definition of syllable weight is identical to the one we have discussed above in the context of the Latin meter. Syllables ending in a consonant (C₀VC-syllables) as well as syllables containing a long vowel (C₀VV-syllables) count as heavy. Syllables ending in a short vowel (C₀V-syllables) are light. Heavy syllables attract stress to the penult, whereas light syllables let it pass to the antepenult. In the first two examples in (5), the penultimate syllable ends in a short vowel and is therefore light. Consequently, stress goes on the antepenultimate syllable. The last two examples contain prefinal heavy syllables, CVC and CVV, respectively, which are therefore stressed. In (5), brackets represent foot structure:

(5)	('an \ddot{i})ma	soul
	('arb \ddot{o})rem	tree-acc
	pe('des)ter	on foot
	for('t \ddot{u})na	fortune

Alternations between penultimate and antepenultimate stress can be observed in the comparative forms of adjectives like *facilis* ‘easy’: *facilior* ~ *faciliōris* ‘easier, m. f. nom ~ gen’, where long prefinal /o/ in the genitive attracts the main stress, which is rejected by the short prefinal /i/ in the nominative. In Latin, all monosyllabic words consist of heavy syllables: *ars* ‘skill’, *mūs* ‘mouse’, *lac* ‘milk’, which are obligatorily stressed. Similarly, since all words must contain a main stressed syllable, disyllabic words are always stressed on their first (leftmost) syllable, independently of the weight of that syllable.

The different representations of light and heavy syllables in moraic phonology are illustrated in (6). We assume, following Hyman (1985), that onset consonants are linked to the same mora as the adjacent vowel, rather than to the syllable node (for the latter view, see HAYES, 1989).

- (6) a. light syllable b. closed heavy syllable c. open heavy syllable
-

The syllable in (6a) is light, because it contains only one mora. The syllable in (6b) is heavy, because it contains two moras. In Latin, the second mora is required, because a postvocalic consonant must be parsed under a mora, provided, of course, that it is tautosyllabic with the preceding vowel. The third syllable has two moras also. In this case the second mora is enforced by the length of the vowel. It is an important hypothesis of moraic phonology that long vowels are always bimoraic (we will shortly return to the representation of contrastive segment duration).

Latin is a quite representative case of a “mora counting” language. Not all languages are so “well behaved”. A language that seems to raise a problem with respect to the hypothesis that long vowels are always bimoraic is Ancient Greek. In this language the structure of the syllable plays a decisive role in predicting the position of the “recessive” accent (STERIADE, 1988; GOLSTON, 1989; KIPARSKY, 2001). Kiparsky formulates the generalization underlying the recessive accent in the following way:

- (7) Recessive accent (KIPARSKY, 2001: 3)
The accent falls on the penultimate syllable if the final syllable is heavy,
otherwise it falls on the antepenultimate syllable.

The examples in (8) and (9) illustrate this generalization. The forms in (8) end in syllables that behave as light; those in (9) end in syllables that behave as heavy.

- (8) Antepenultimate accent in words ending in a light syllable or final VC-syllable
- | | |
|------------|----------------------|
| soómata | ‘bodies-Nom. Pl’ |
| epaídeusa | ‘I educated-Aor.’ |
| ánthroopos | ‘person-Nom.’ |
| epaídeusan | ‘they educated-Aor.’ |
- (9) Penultimate accent in words ending in a heavy syllable
- | | |
|-------------|-------------------|
| paideúoo | ‘I educate-Pres.’ |
| anthróopoon | ‘person-Gen. Pl.’ |
| lipóthriks | ‘balding’ |

At first sight, it seems as if in Ancient Greek a closed syllable counts as light, as is the case with the final syllables in the forms *ánthroopos* and *epaídeusan* in (8). This, however, is contradicted by the word-final syllable of *lipóthriks* in (9), which form suggests that a closed syllable does add weight to the syllable, on the condition that it is closed by more than one consonant.

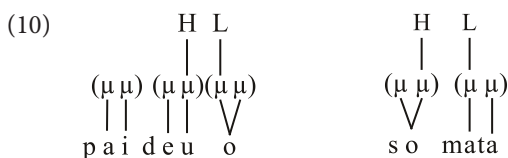
To explain the fact that only closed syllables ending in at least two consonants behave as heavy, Steriade (1988) proposes that, if a word final consonant is not visible to foot formation, it is defined as extrametrical. A **word-final** syllable closed by just one consonant therefore behaves as light, while syllables closed by a consonant cluster are predicted to behave as heavy.

The forms *paideúoo* and *anthróopoon* in (9) show that a syllable containing a long vowel, whether open or closed, is heavy. This is expected in moraic phonology, because long vowels are always bimoraic in this theory. The heavy-light distinctions of Ancient Greek thus seem to be identical to the ones of Latin; syllables ending in a short vowel (C_0V -syllables) are light; syllables with a long vowel and closed syllables are heavy. Just like Latin, then, Ancient Greek recognizes the weight distinctions in (6). There is, however, one important difference between Ancient Greek and Latin, which is the extrametrical nature of the final consonant in Ancient Greek.

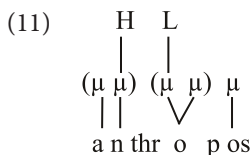
Nevertheless, the hypothesis that long vowels are bimoraic in Ancient Greek raises an interesting problem. Consider the forms *epaídeusa*, *ánthroopos* and *epaídeusan* given in (8). These forms seem to indicate that a long vowel (or a diphthong for that matter) can be skipped by foot formation. The same impression is created by Kiparsky’s definition of regressive accent, given in (7), especially the second part, where it is stated that the recessive accent skips a prefinal syllable, irrespective of its weight, when the word-final syllable is light. How can that happen if long vowels (and diphthongs) are bimoraic and therefore heavy? Were this true, we would face a serious problem. Extrametricality would not be helpful here, since only categories (segments, moras, syllables, feet) that are final in the stress domain can be extrametrical, as is the case with the word-final syllables in Latin or the word-final consonants in Ancient Greek. As it turns out, however,

the problem is illusory. As we will show, the way recessive accent is marked in Ancient Greek words appears to be phonetic rather than phonological.

Following Allen (1973) and Golston (1989), we assume that Ancient Greek syllables are footed as moraic trochees ('μμ) assigned from right to left. We furthermore adopt Sauzet's (1989) assumption that the relevant pitch melody that marks the stress is HL. According to this understanding, L docks onto the prominent, i.e. main-stress, position of the word, which is the head vowel of the word-final foot. The H is assigned to the tone-bearing unit immediately to the left of the one to which L is associated. In a word like *paideúoo* (cf. (9)) the last syllable, which is heavy, coincides with the final moraic trochee. The H element of the tonal melody therefore appears on the mora immediately to the left of the final (heavy) syllable. In a word like *soómata* (cf. (7)), comparatively, the final syllable is light, and it can therefore occupy the weak part of a moraic trochee. In words of this type, the final moraic trochee contains two syllables. Here, the H element of the pitch melody appears on the mora immediately to the left of the penult syllable. We clarify this with the representations in (10), where we dispense with syllable structure and delimit the moraic trochees with brackets.



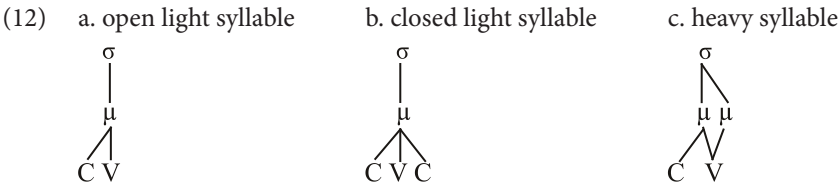
As we show in (11) below, in this account word internal long vowels no longer behave exceptionally. Just like the long vowels in final syllables, they are bi-moraic, exactly as predicted by moraic theory. Prefinal long vowels are therefore not skipped. They form a moraic trochee on their own of which the left mora is associated with the low tone of the HL pitch melody. The high tone regularly goes to the mora preceding the one characterized by the low tone.



The postulation of the HL pitch accent melody allows us to maintain the important claim of moraic theory that all long vowels are bimoraic and therefore create heavy syllables in languages that recognize weight distinctions. A more abstract way of looking at the Ancient Greek recessive accent would be to consider that the phonology marks the main stress as low toned (L), the low character of

which is phonetically enhanced by the rise of the immediately preceding syllable. In sum, Ancient Greek is like Latin in making the distinctions in (6).

There are languages that classify rhyme types differently with regard to the light-heavy distinction. Not all languages treat closed syllables as heavy. In some languages, like Buriat, a Mongolian language spoken in Russia, or the Central American Language Huasteco Mayan, closed syllables count as light (cf. HAYES, 1995; GORDON, 2006, among others). In these languages, then, closed syllables are monomoraic. This is illustrated in (12).



In still other languages, the moraic status of the coda consonant depends on its sonority degree. For example, in some languages sonorants count as moraic, while obstruents do not, as in the Canadian indigenous language Kwakwala (GORDON, 2006; ZEC, 1988). We thus arrive at the following typology of weight patterns (R represents a sonorant consonant; O represents an obstruent).

(13)
A typology of weight patterns

	heavy (= bimoraic)	light (= monomoraic)
The Latin type:	CVV, CVC	CV
The Buriat type:	CVV	CV, CVC
The Kwakwala type:	CVV, CVR	CV, CVO

Not all languages that recognize weight distinctions have a contrast in vowel duration (cf. GOEDEMAN, 2010, p. 659). In Brazilian Portuguese, for instance, which is a language without contrastive long vowels, closed syllables count as heavy and open syllables as light, as argued by many (BISOL, 1992; WETZELS, 1992, 2007; MAGELHÃES, 2004; MASSINI-CAGLIARI, 2005; HERMANS & WETZELS, 2012). Similarly, the indigenous Brazilian language Bakairi has no contrast between short and long vowels. Furthermore, non-vocalic segments may not occur in the syllable coda. Syllables contain either short vowels or diphthongs. The latter count as heavy for the sake of stress assignment (WETZELS & MEIRA, 2010).

One very robust generalization emerging from the cross-linguistic study of quantity-sensitive stress systems is that onsets do not contribute to syllable weight. Only postvocalic consonants can have that property, provided that they are located in the same syllable as the preceding vowel. However, it must be mentioned that there are a few languages where onsets do have a role to play in the allocation

of stress. One of the clearest examples is Pirahã (EVERETT & EVERETT, 1984; EVERETT, 1988). According to these authors, Pirahã word stress is as follows:

- (14) Stress the rightmost heaviest syllable of the last three syllables in the word.

Pirahã has a three-syllable window at the right word edge. Within this window, the rightmost heaviest syllable is selected. “Heaviness” is defined according to the hierarchy in (15).

- (15) $PVV > BVV > VV > PV > BV$
 (P = a voiceless plosive, B = a voiced plosive, VV = long vowel or diphthong;
 $x > y$ means x is heavier than y).

A few examples illustrating Pirahã stress are given in (16).

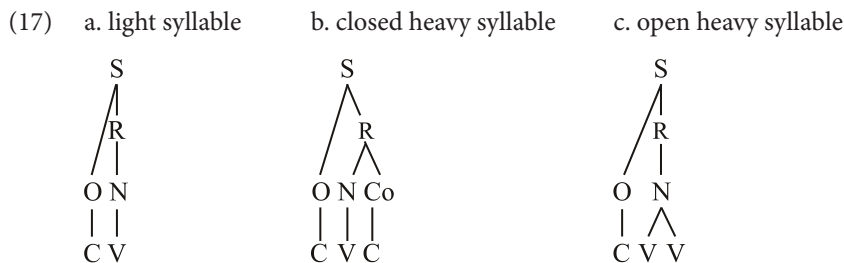
- | | | |
|------|------------------|-----------------|
| (16) | a) káo.ba.bai | almost fell |
| | b) káa.gai | word |
| | c) pá.ba.gi | toucan |
| | d) ti.pó.gi | species of bird |
| | e) pa.ba.pá | Amapá |
| | f) ʔa.pa.báa.si | square |
| | g) bíi.ao.ii | tired |
| | h) poo.gái.hi.ai | banana |

The forms (a-d) show that a voiceless onset consonant creates a more prominent syllable than a voiced onset consonant, everything else being equal. Examples (d, e) demonstrate the rightwards orientation of stress in case two or more eligible syllables are of equal prominence. The form in (f) shows that a syllable with a long vowel is heavier than a syllable with a short vowel. Example (g) proves that a syllable with an onset is heavier than a syllable without an onset, if the vowels are of equal quantity. Finally, example (h) shows that a syllable outside the three syllable window cannot be stressed, even if it is heavier than any of the syllables within the window.

The weight distinctions made in Pirahã are partly familiar. We have seen, for instance, that, in languages that distinguish heavy and light syllables, long vowels in open syllables count as heavy, whereas syllables ending in a short vowel are light. On the other hand, Pirahã seems to falsify the hypothesis of moraic theory that onsets do not contribute to a syllable’s weight. This language contradicts this

hypothesis in two ways, because both the presence of an onset consonant as well as its phonological properties independently add weight to the syllable. Pirahã, then, poses a potential problem for moraic theory, and it remains to be seen if it can be solved in a satisfactory way within this framework. One alternative way of looking at Pirahã would be to consider it a “mixed prominence” system, where both weight (long vs. short vowels), the fact that generally CV syllables are preferred over onsetless syllables, as well as the (more optimal) degree of sonority difference between onset and nucleus play a role in the selection of the main stressed syllable, as suggested in Wetzels & Meira (2010). The existence of other types of mixed prominence systems has also been attested, such as the one found in the Peruvian language Nanti, described by Crowhurst & Michael (2005). If this way of looking at Pirahã is correct, the explanation of the stress-attracting properties of onsets lays outside of mora theory, which is primarily designed to account for weight (or duration) differences.

Pirahã is quite exceptional. In the great majority of languages with quantity-sensitive stress the nature of onset consonants is irrelevant. Moraic phonology is designed to explain the role of syllable weight and is by and large successful in explaining it. The other two theories of the syllable we have mentioned above have no straightforward explanation for this fact. In order to see this, we must return to the typology in (13). We have seen there that in some languages both long vowels and closed syllables create heavy syllables. In a theory with subsyllabic constituents the following are the relevant primitives (N = Nucleus, R = Rhyme, Co = Coda, O = Onset, S = syllable, C = consonant, V = vowel):



It is generally accepted that the coda is filled by consonantal segments. The structural consequence of this is that a closed syllable is represented as a branching rhyme, whereas a long vowel is parsed as a branching nucleus. To ensure that these syllable types interact correctly with foot formation we have to state that a branching nucleus or a branching rhyme are not allowed in the unstressed part of a foot, as in the Latin case. For Buriat-type languages we have to say that a branching nucleus is not allowed in a foot’s unstressed syllable, whereas branching rhymes, which behave as light in this language, can freely occur in that position.

Kwakwala-type languages are basically like Buriat-type languages, the difference being that sonorant consonants are allowed in the nucleus, whereas obstruents are not.

It appears, then, that in theories with subsyllabic constituents we must account for the interaction between syllable structure and foot formation by referring to the branching nature of the rhyme and the nucleus, which are to be banned – either both the branching rhyme and the branching nucleus, or just the branching nucleus – from occurring in the unstressed part of the foot. However, one wonders why only the branching structure of the embedded constituents are relevant for the computation of the syllable weight. Why is the branching status of the syllable constituent as a whole irrelevant? Notice that the exclusion of a branching syllable node from the foot's unstressed position would predict the existence of languages where the presence of the onset has the effect of making a syllable heavy. This prediction is not correct, at least if we leave aside Pirahã, and a few other languages. In the great majority of the world's languages, the branching status of the entire syllable node is irrelevant as a contributor to the weight of a syllable.

The X'-theory of the syllable suffers from the same problem. In languages where closed syllables and long vowels are heavy, both a branching N' and a branching N must be excluded from a foot's unstressed syllable. This is shown in (18), which is the X'-equivalent of (17).

- (18) a. light syllable b. closed heavy syllable c. open heavy syllable



In Buriat-type languages (18b) would be considered light. Therefore, only the branching N must be excluded from the foot's unstressed part. Again the question is why the branching nature of N and N' may affect syllable weight, but not the branching nature of the syllable node. No principled answer to this question is possible in non-moraic theories of the syllable.

In the moraic theory onsets do not contribute to weight simply because they are absent at the relevant levels of the representation. For foot formation, two levels are relevant, the syllable and the mora. In some languages, foot formation just takes syllables into account. When this happens moraic structure is irrelevant and any syllable can appear in the foot's unstressed position. Alternatively, foot formation only considers moraic structure. In a language where this is the case,

a syllable with two moras cannot occupy the unstressed part of the foot. In both situations the presence or absence of an onset is irrelevant.

We can conclude, then, that moraic phonology explains a crucial property of the great majority of the world's stress systems: onsets do not contribute to weight. We will next turn to a second phenomenon in which moras play a significant role: compensatory lengthening.

2. Moraic conservation

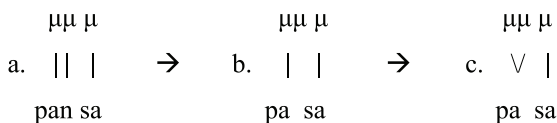
According to Hayes (1989) the phenomenon of Compensatory Lengthening provides us with a supplementary argument for moraic theory. In this section, we present a few famous cases of Compensatory Lengthening, which will serve to clarify this claim.

2.1 Instances of Compensatory vowel lengthening

According to Whitney (1889, p. 84), compensatory lengthening (henceforth CL) can be understood as the “absorption by a vowel of the time of a following lost consonant”. Although Whitney’s early definition does not cover all of the types of compensatory (vowel) lengthening that are known from the literature (cf. DE CHENE & ANDERSON, 1979; HOCK, 1986; WETZELS & SEZER, 1986; HAYES 1989; RIALLAND, 1993; TOPINTZI, 2006; BELTZUNG, 2009), it certainly covers most of the well-documented cases. Particularly interesting in Whitney’s definition of CL is the intuition that there is something like “phonological time”, which enjoys some degree of autonomy with regard to the featural properties of a segment and which can, within certain limits, be redistributed over the phonetic string, as is also predicted by Hayes. A straightforward example taken from Ancient Greek is known in the literature as the “second compensatory lengthening”.

The Second Compensatory Lengthening (SCL), which according to Bartoněk (1966, p. 68) was completed around 900 B.C., is restricted to the secondary intervocalic cluster *-ns-* (<*nt*, *ntj*) and the primary word final cluster *-ns#* or *-nts#* (>*-ns#*): Attic-Ionic φηνᾶντς → φηνᾶνς → (SCL) φήνᾱς ‘showing-Aor’. The dialectal reflexes of the sequence /ns/ show a wide range of variation, also depending on its position in the word (WETZELS, 1986; 2006). In (19), compensatory lengthening is described, following Hayes (1989), within the framework of moraic theory. The idea is that a mora’s content can be deleted, but the mora itself is not. Hayes calls this ‘moraic conservation’ (HAYES, 1989, p. 285).

- (19) *πάντ-γα ‘whole-NOM.SI.FEM’ > πᾶνσα /pansa/ > Ionic Attic πᾶσα /pa:sa/

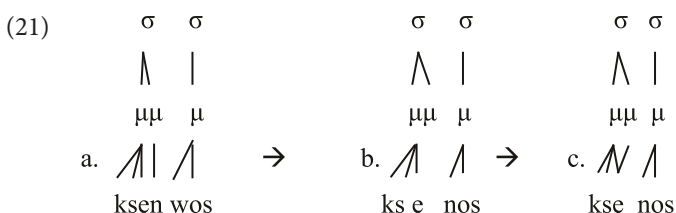


In (19b), [n] is deleted from the segmental string, while its mora is preserved. The segmentally unaffiliated mora is subsequently linked to tautosyllabic [a], which is realized as a long vowel: [pa:sa] (19c).

In the type of CL just given it is the coda consonant that is removed. But moras can also be freed as a consequence of segment migration. Even prior to 800 B.C., digamma (written *F*, phonetic [w]) was lost in Attic and Ionic when followed by a tautosyllabic sonorant segment: *woikos* > *oikos* ‘house’, *ksenwos* > Att. *ksenos* ‘stranger’. In most of the dialects, *w* disappeared without leaving any trace on the phonetic surface. However, in East Ionic (and partially in Central Ionic) as well as in the dialects of Thera, Cyrene, Cos, Rhodes, and Western Argos, the loss of postconsonantal *w* was accompanied by the lengthening of the preceding vowel:

- (20) *odwos* > Ion. *o:dos* ‘threshold’ *orwos* > Ion. *o:ros* ‘boundary’
kalwos > Ion. *ka:los* ‘beautiful’ *ksenwos* > Ion. *kse:nos* ‘stranger’

It is unlikely that the class of words exemplified in (20) has gone through an intermediate stage in which *w* was brought into coda position by metathesis: if the long vowel were to be explained as the result of coda *w* deletion or *Vw* contraction, we would expect all tautosyllabic *Vw* sequences in these dialects to have yielded long vowels, but this did not occur. It is therefore plausible to suggest that the deletion of an onset segment may trigger the lengthening of the vowel in the preceding syllable as a consequence of the reassociation between moras and segments: after *w* was lost (or had lost its segmental status) the consonant preceding *w* moved to the syllable onset, thereby vacating a mora that was absorbed by the preceding vowel, and consequently became long, the so-called “double flop”, as illustrated below:

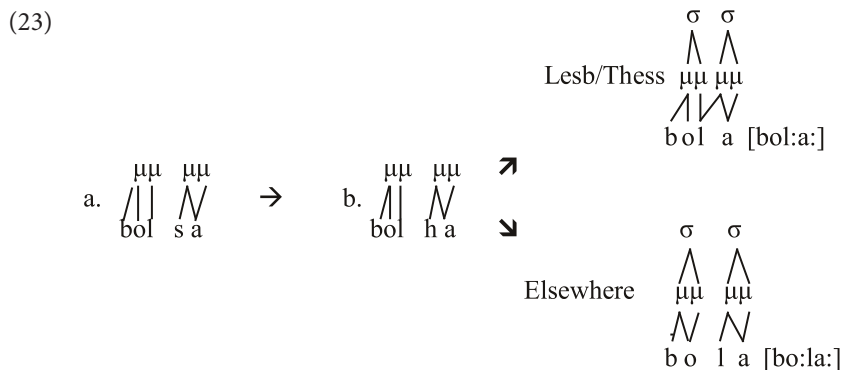


Another example of vowel lengthening by way of the “double flop”, although somewhat more controversial, is known as the “first compensatory lengthening”.

Relevant to our discussion is the fate of **j* and **s* in the sequence *VS{j,s}V*, where *V* stands for vowel and *S* for sonorant consonant. In the non-Aeolic dialects, the loss of both *s* and *j* was eventually accompanied by the lengthening of the preceding vowel, a process known as the “first compensatory lengthening”. CL occurred in words derived historically from *V₁SjV₂*, except when *V₁* was /{a, o}/ or *S* was /l/. Otherwise, *VSjV* yielded *VSSV* in the Lesbian and Thessalian dialects, but *V:SV* elsewhere. However, *VSsV* (as well as *VsSV*, both probably through an intermediate stage *VShV* and *VhSV*) generally produced *VSSV* in Lesbian and Thessalian and *V:SV* elsewhere. Some examples are provided in (22):

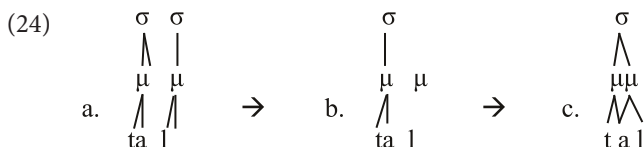
(22)		Lesb./Thes.	Elsewhere
<i>*klin-jo:</i>	‘tend’	<i>klinno:</i>	<i>kli:no:</i>
<i>*phther-jo:</i>	‘destroy’	<i>phtherro:</i>	<i>phthe:ro:</i>
<i>*awer-jo:</i>	‘lift’	<i>aerro:</i>	<i>ae:ro:</i>
<i>*g^wolsa:</i>	‘council’	<i>bolla:</i>	<i>bo:la:</i>
<i>*a:ngelsa</i>	‘I announced’	<i>a:ngella</i>	<i>a:nge:la</i>
<i>*esmi</i>	‘I am’	<i>emmi</i>	<i>e:mi</i>

Among the many different accounts given of the sound changes exemplified in (22), the one proposed in Wetzels (1986) is based on moraic conservation accounting for both gemination and vowel lengthening, as illustrated in (23):



In Lesbian and Thessalian, after the loss of *h*, the sonorant consonant attaches to the onset of the following syllable without leaving its original coda position, thus becoming a geminate. In the other dialects, the sonorant consonant migrates to the onset position, vacating the mora in the coda, which is absorbed by the preceding vowel. A similar account explains the consonant gemination and vowel lengthening from original *VSjV* sequences in the relevant dialects.

Yet another type of CL is one in which a vowel is lost with subsequent CL of the vowel of the preceding syllable. The pattern can be schematized as VCV > V: C. According to Hock (1986), this phenomenon is attested in many languages. Hayes illustrates this type of CL with an example from Middle English. The example is *tale* ‘tale’.

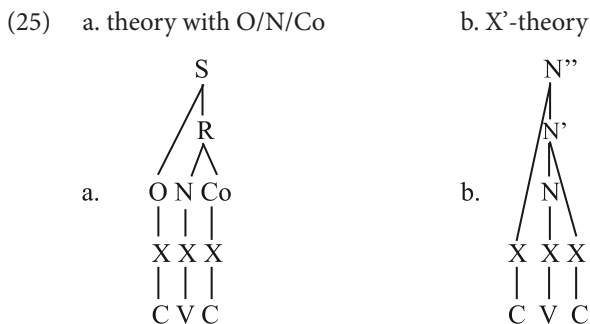


After the loss of word-final schwa, part of the syllable structure is deleted by a principle called “parasitic delinking” by Hayes (1989, p. 268). This principle applies whenever a syllable lacks an overt nuclear segment. The effect of schwa deletion and parasitic delinking is shown in (24b). The structure in (24b) allows the association of the nucleus /a/ of the first syllable to the more freed by schwa deletion. The stray consonant is also attached to the second mora.

Having presented three representative cases of CL and having shown how they are accounted for in moraic theory we can now compare the moraic approach to CL with alternatives that do not recognize the mora as a phonological primitive.

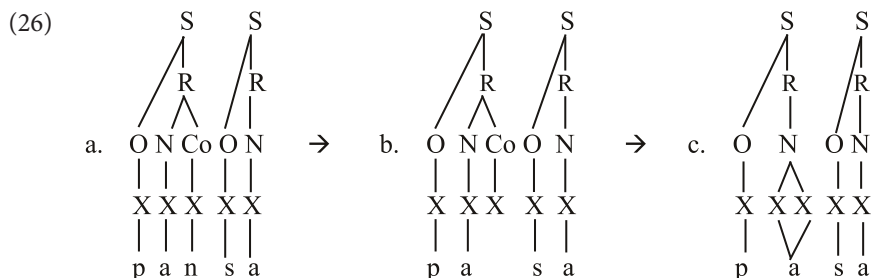
2.2 Asymmetries in CL

In order to see how CL can be accounted for in different models representing word-prosodic structure, we have to make explicit what exactly the interface is between syllable structure and segments in the non-moraic approaches. Normally, these theories posit a layer of timing units that mediates between the syllabic structure and the segmental structure (cf. LEVIN, 1985 and BLEVINS, 1995). We clarify this with the structures in (25), which replace those in (1) and (2), respectively.



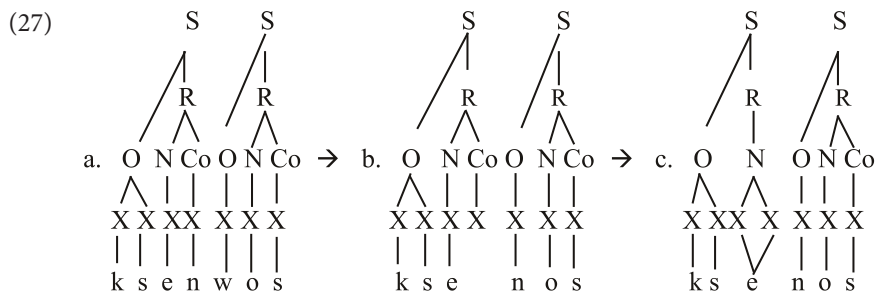
As we will show, these models can account for all the CL-types we have presented in the previous subsection as easily as mora theory. The independent existence of the timing tier allows for segments to be deleted with timing slot conservation. The “empty” timing slot is then attached to an adjacent segment. We show this with the representation in (26a) only, since the same argumentation is valid for the X'-theory.

The type of CL where the coda consonant is removed (with subsequent CL) proceeds as follows:



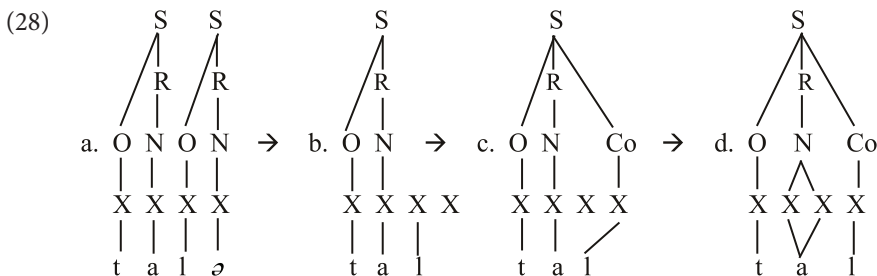
The underlying structure /pansa/ is syllabified as in (26a). Then the coda consonant is deleted, leaving behind an empty timing unit, as shown in (26b). The empty X-slot is then filled by the vowel and the syllabic structure is adapted to accommodate the long vowel in the nucleus, as shown in (26c).

The cases where CL is the consequence of segment migration are also easy to handle in the theories containing X-slots. We illustrate this in (27).



The underlying string of segments /ksenwos/ is syllabified as in (27a). After the deletion of /w/, /n/ migrates from the coda to the onset of the next syllable, as is shown in (27b). The shift of /n/ from the coda to the onset is a consequence of the fact that onsets are filled whenever possible. The X-slot freed by /n/ is now filled by the vowel which becomes long. This enforces the restructuring of the syllable, since codas cannot host vowels. Both changes are illustrated in (27c).

In theories containing X-slots the type of CL that can be schematized as VCV > V:C is accounted for in the following way (HAYES, 1989, p. 267).



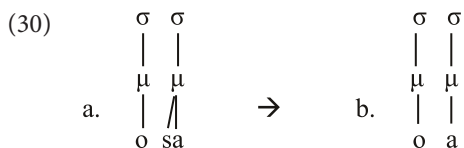
First the underlying structure /talə/ is syllabified, as is shown in (28a). Then schwa-drop applies, leaving behind an empty X-slot. Since the second syllable has no longer a nuclear segment, parasitic delinking applies. This creates the representation in (28b). Now several processes apply whose task it is to fill the empty X-slot. First /l/ shifts to the final X-slot. This is shown in (28c). The migration of /l/ leaves behind an empty X-slot, which can be filled by the spreading vowel. This is shown in (28d).

X-slot theories as well as moraic theory appear to be able to account for all the important cases of CL. Is there a way to decide which approach is the better one? Probably the most important argument of Hayes' paper is based on the asymmetry between onset and coda consonant as regards the possible consequences of their loss.

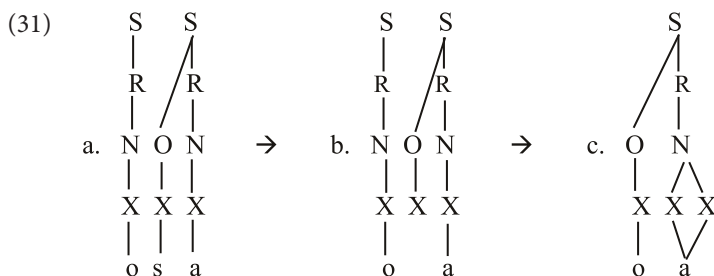
We have seen that the loss of an onset consonant can only lead to CL if it entails the migration of a preceding consonant from coda to onset. This asymmetry can easily be explained in the moraic approach. Impossible compensatory changes include the following (HAYES, 1989, p. 281; but see TOPINSKI, 2006, for a different point of view):

- (29) #/sa/ can never become # [a:]
 /osa/ can never become [oa:] or [o:a]

The fact that the loss of an onset consonants in these sequences does not lead to CL is predicted by the moraic approach. In moraic theory, onset consonants do not have their own mora. Hence, the deletion of an onset consonant never results in an empty mora, which is available for reassociation to a segment that is within its reach. We show this in (30).



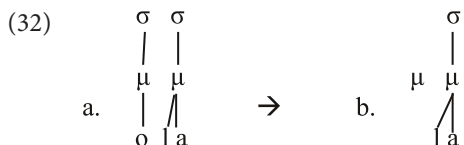
In theories postulating X-slots, this asymmetry cannot be explained. Since every segment is dominated by its own timing unit, in principle every segment can be deleted without the corresponding timing slot being lost in the deletion process. Consequently, one would expect to find cases where the loss of an onset consonant is compensated for by the lengthening of the nucleus, as is shown in (31).



X-slot theory therefore predicts the existence of unattested phonological changes.

X-theory encounters a similar problem in being unable to account for the asymmetry typical of the type of CL that occurs in VCV sequences as a consequence of the loss of an adjacent nucleus, i.e. the *talə* > *ta:l* case. This type of CL can happen only due to the loss of a following vowel. It never happens when a preceding vowel is deleted: $V_1C_1V_2 > C_1V_2$ does not exist. According to Hayes (1989:286) this can be explained easily in the moraic approach to CL, whereas it cannot be explained in theories using X-slots.

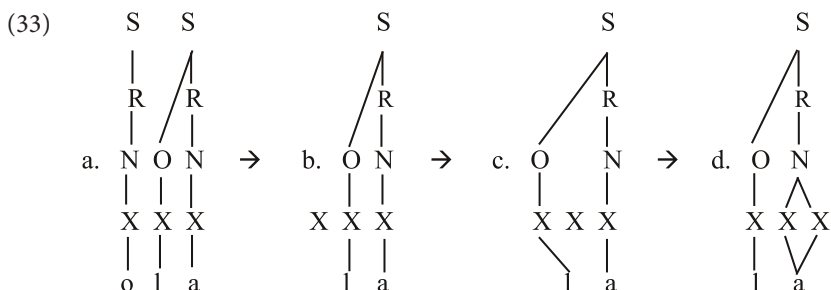
In (32) we show how moraic theory cannot account for a CL type like $V_1C_2V_2 > C_2V_2$ (*ola* > *la:*).



(32a) represents the regular syllabification of the sequence /ola/. In (32b) /o/ is lost and syllable structure is partially erased by parasitic delinking. Now the question is: why can /a/ not spread to fill the mora on its left? According to Hayes

(1989, p. 286), the spreading of /a/ to the stray mora could only occur by crossing the line that connects /l/ to its mora, which is prohibited by a principle known as the “no crossing constraint”.

No such simple explanation is possible in theories containing X-slots. Consider the structures in (33):



Example (33) represents the mirror image of (28). There we have seen that /l/ shifts to a new position on its right, so that its original position can be filled by the spreading of the vowel located on its left. As in the case of (28), since all consonants and vowels are dominated by at least one timing unit, (33) creates the conditions for a ‘double flop’: /l/ may shift to the left, vacating its original position and thus creating the possibility for /a/ to spread to the freed mora, as shown in (33d). Obviously, this potential of X-theory is undesirable, because it predicts the existence of unattested changes.

Having shown that moraic theory can explain a number of asymmetries in the nature of compensatory processes for which non-moraic theories have no straightforward explanation, we will in the next section compare these theories regarding their way in dealing with the versatile behavior of geminate consonants as contributors to syllable weight.

3. Consonantal length

Many languages have a phonological distinction between long and short consonants. Japanese is a good example. In (34) we provide a minimal pair showing this contrast, taken from Tsujimura (2007).

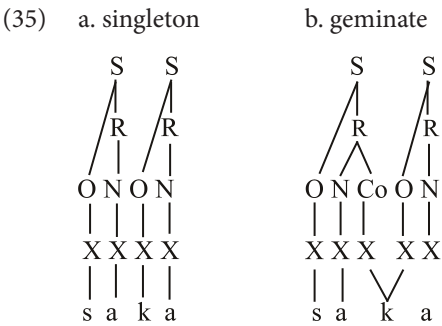
- (34) [saka] ‘hill’
[sak:a] ‘author’

In this section, we compare the moraic approach to consonantal length with alternative approaches based on timing units. We show that, in the domain

of stress, the two approaches make rather different predictions with respect to the behavior of long consonants. Interestingly, sometimes the moraic approach makes the correct prediction and sometimes the X-slot-theory.

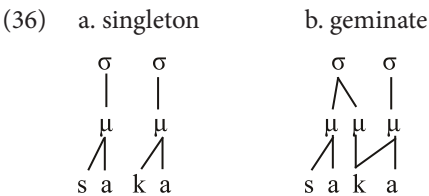
3.1 The behavior of geminates with respect to quantity-sensitive stress

In theories based on X-slots, the contrast between long and short consonants is expressed in terms of the number of X-slots to which a consonant is attached; a short consonant, or singleton, is attached to one X, whereas a geminate is linked to two X's. In (35) we demonstrate how these representations interact with syllable structure (assuming a O/N/Co-theory of the syllable).



We observe that an intervocalic singleton is syllabified in the onset of the second syllable. An intervocalic geminate, on the other hand, is syllabified simultaneously as coda and onset of two consecutive syllables.

Similarly, in the moraic approach to consonantal length, the contrast between short and long consonants is expressed in terms of the number of moras to which the consonant is linked. However, in this theory a single consonant has no mora attached to it, whereas a geminate consonant is linked to one mora in lexical representation (HAYES, 1989, p. 256-257). In (36) we show how these distinctions interact with syllable structure.



A short intervocalic consonant is syllabified in a syllable onset only. In Hyman's (1985) version of moraic theory, which we have adopted here, this means that the consonant is linked to the mora of a following vowel, as in (36a). On the other hand, a geminate consonant is linked to two consecutive moras. The left mora is the one that defines the consonant as being long, the right mora is the one that dominates the following nucleus. Given that only consonants that have the effect of closing a syllable can be moraic, the mora which defines the consonant as intrinsically heavy (geminate) can occur only as the right mora of a bimoraic syllable. Both aspects of the syllabification of an intervocalic geminate are shown in (36b).

The interesting question to ask is whether the representations in (35b) and (36b) make different predictions. Fortunately, they sometimes do, and we can therefore test which approach to consonantal length is to be preferred.

The X-slot approach predicts that a short consonant in the syllable coda and a geminate consonant will always behave identically with respect to quantity-sensitive stress. This is a consequence of the fact that the left timing unit of the geminate is always syllabified in the syllable coda, as we have shown in (35b). If a coda consonant makes a syllable heavy, then so does the first part of a geminate. Latin is a language of this type. A further prediction of X-theory is that, if a closed syllable behaves as light, then so does a syllable closed by the first part of a geminate. Theories of the syllable containing X-slots account for languages of this type by saying that (only) a branching nucleus is prohibited in a foot's unstressed syllable. Halle and Clements (1983) present data from Selkup suggesting that this language is precisely of this type. In Selkup, the rightmost syllable containing a long vowel receives stress, showing that the stress rule is quantity sensitive. If there is no long vowel, the word-initial syllable is stressed. A few examples are given in (37).

(37) Stress in Selkup

- | | |
|---------------|--------------------|
| a) qu'mo:qi | 'two human beings' |
| b) 'u:ciqo | 'to work' |
| c) u: 'cɔ:mit | 'we work' |
| d) 'qum i nɪk | 'human being, DAT' |
| e) 'amirna | 'eats' |
| f) 'u:cik:ak | 'I am working' |
| g) 'esyk:a | 'it happens' |

The forms (37a-c) demonstrate that long vowels attract stress. The forms (37c-e) show that closed syllables do not attract stress and therefore behave as light syllables. Finally, the forms (37f,g) show that geminates pattern with closed syllables in not attracting stress. Consequently, Selkup confirms the prediction made by theories recognizing X-slots: closed syllables and geminates always form a natural class with regard to the question whether or not they add weight to the syllable.

The moraic approach to consonantal length predicts that, in quantity sensitive languages, geminates and closed syllables do not always behave uniformly. This is because in moraic theory the moraic status of a coda consonant is determined on a language-specific basis: a coda consonant may be dominated by a mora of its own, or it attaches to the mora of preceding nucleus. Syllables containing non-moraic coda consonants obviously behave as light syllables. Geminates, however, are moraic by definition. From this it follows that a syllable closed by a geminate is always heavy, even in a language where closed syllables behave as light. It is clear, then, that a language like Selkup is problematic for the moraic approach to consonantal length, which cannot explain the identical stress patterns in the forms (37e) and (37g). Specifically, it predicts that the form (37g) should have penult stress, because the penult syllable is closed by a geminate, which is always moraic.

Interestingly, however, there are also languages where the prediction of the moraic approach to consonantal weight is borne out. Languages where closed syllables behave as light, unless they are closed by a geminate, do exist. The Cahuilla language of Southern California (USA), analyzed in Hayes (1995), is a famous case. The following data are taken from Hayes (1995). The subscript ₂ marks secondary stress on the following syllable.

(38) Stress in Cahuilla

- | | |
|---|-------------------------|
| a) 'ta.ka. ₂ li.tʃem | one-eyed ones |
| b) 'tʃe.xi.wen | it is clear |
| c) 'tax.mu. ₂ ʔ at | song |
| d) 'he.ʔi. ₂ ka.kaw.la. ₂ .qa | his legs are bow shaped |
| e) 'qa:n. ₂ ki.tʃem | palo verde, PL' |
| f) 'tʃex.xi.wen | it is very clear |

In this language, moraic trochees are assigned from left to right, usually creating an alternating rhythm of stressed and unstressed syllables. The word-initial foot is dominant in the stress domain, which means that main stress is word-initial. Curiously, the alternating rhythm is interrupted in forms containing a long vowel, as can be seen in examples (38d,e). In these words, foot construction is started anew immediately after the syllable containing the long vowel, creating a sequence of two stressed syllables. This shows unambiguously that long vowels attract stress, implying that the language is quantity sensitive. However, the same is not true for closed syllables: foot construction is not resumed after a closed syllable, as is shown by example (38c). Furthermore, closed syllables are found in the unstressed part of a foot, again showing that coda consonants are not moraic in this language. This is demonstrated by the words in (38a) and (38d-f). Crucial is the behavior of geminates consonants, which behave like syllables containing long vowels with regard to the resumption of foot construction. This is shown by

the example in (38f), which shows a sequence of two stressed syllables, the first of which is closed by the left part of a geminate consonant. The word-prosodic system of Gahuilla is predicted to exist by mora-theory, but is problematic for the X-slot theory, which would predict solidarity between syllables closed by a simple consonants and syllables closed by the first part of a geminate.

It seems that it is not possible to come to a firm conclusion. Sometimes theories that recognize X-slots fair better in accounting for the versatile behavior of geminate consonants, whereas in other cases mora theory makes the right predictions. One way out of this dilemma may be to suppose that in languages in which neither geminate consonants nor single coda consonants make syllables heavy, the geminates are actually a sequence of two identical single consonants. This alternative way of representing long consonants, for which each time independent evidence should be available, would be easy to accommodate in mora theory, which could then be able to account for Selkup stress. The same hypothesis would not help the X-slot theory to account for stress in Gahuilla, since, by definition, in X-theory each segment is dominated by an timing unit.

Conclusion

In this paper we have compared non-moraic theories of the syllable and moraic phonology with respect to three phenomena: their modeling of syllable weight distinctions, their success in accounting for the attested (and undisputed) types of Compensatory Lengthening, the way they represent geminate consonants. We have shown that moraic theory is designed to capture the fact that onsets are irrelevant with regard to rules of stress placement. Other theories of the syllable cannot so easily explain this fact, in the sense that the irrelevance of the onset can only be stipulated. It does not follow intrinsically from the theory, as in moraic theory. We have noted, however, that Pirahã, and maybe few other languages not discussed in this paper, is problematic for moraic theory, because in such languages onsets do seem to matter for the assignment of stress, although, maybe, an alternative explanation is possible.

Moraic theory is superior in the domain of CL. Here it can explain two asymmetries. Firstly, the loss of an onset cannot cause compensatory lengthening of an adjacent segment, unless in the specific circumstance in which its deletion leads to the resyllabification of the preceding coda consonant, which then creates a free mora, as we have seen in Ancient Greek. Secondly, Vowel Lengthening as a compensation for the deletion of another vowel may only affect a vowel that immediately precedes the deletion site.

Finally, with respect to the versatile behavior of geminate consonants, which sometimes add weight to the syllable in which they act as codas, but sometimes not, the results are inconclusive.

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